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THE LOGIC OF THE SCIENCES.[1]

THE work of science is carried on by an increasing number of special sciences, developed in response to the necessity of increasing specialization and division of labor. This elaboration of science has been going on with startling rapidity in recent years. Lord Macaulay tells us that in his day the sum of human knowledge was of such small compass and was increasing so slowly that an active student might fairly comprehend all of its main facts and principles in a single lifetime. But this is far from true to-day. Not only can no one now keep up with the new learning, but no one can acquire in any detail a tithe of the existing learning. To take all of the different courses offered in any one year at any one of our great universities, such as Columbia or Chicago, would require the time of an average student for four or five hundred years. Our educational industry is thus busy multiplying thought-tools for all of our social occupations, and to secure effective cooperation between these occupations it is necessary for everybody to have some comprehension of the main problems of each, and of the means of solving these problems. Each of the different branches of education is thus attacking the social problem from a different point of view. Each abstracts, for the sake of intellectual convenience, certain aspects of the problem of developing the larger union; and as these branches become more efficient in producing truths useful in dealing with those aspects, they employ more and more the scientific method. If, therefore,

[1] A chapter of a forthcoming book on Social Reconstruction.

we are to understand the scientific method of attacking the social problem, we must inquire how the special sciences are related to each other in the use of this method.

Since the days of Auguste Comte, students have been clearly aware that certain grand divisions of science arrange themselves logically in a hierarchy according to their degree of abstractness and of consequent scientific development. Comte stated the series as follows: mathematics, astronomy, physics, chemistry, biology, psychology (transcendental biology), sociology—each of these terms, standing for a scientific point of view, or group of studies, becoming more numerous and more intensively specialized As these sciences are only divisions for convenience in one logically continuous social function of systematic reflection, there are no, and can be no, definitely fixed boundaries between the sciences. Indeed, the old boundaries are continually being obliterated by new sciences, such as symbolic logic, mathematical astronomy, astrophysics, physical chemistry, chemical biology, biological psychology, and social psychology. There seems to be in particular no logical justification for placing astronomy as one of the grand divisions of general science, since it stands for no general conception different from those of mathematics, on the one hand, and physics, on the other. Logic also should be placed first as the science of intellectual method in all problems. As the science of thinking, logic sharpens the thought-tools — categories — with which all science must work. It sharpens them—makes them valid, as we shall see later—by means of the categorical experience of unity.

Each of these larger divisions of science, indeed, is distinguished by the fact that it constructs its system of conclusions or truths from the point of view of a single conception, which we find we have to use continually in interpreting our universe. These major conceptions are unity, magnitude, energy, matter, life, consciousness, and society;

and the divisions of science which respectively elaborate their meaning for us are logic, mathematics, physics, chemistry, biology, psychology, and sociology. Of course, within each major conception are developed numerous subordinate conceptual distinctions: as, for example, in unity are the concepts of continuity, consistency, harmony, likeness, order, peace, and their opposites. Each of these grand divisions of science, in elaborating its own main conception, employs necessarily without much questioning the conceptions developed by the logically and "positively" prior divisions, but not so distinctly those of the later divisions.[1] This is what Comte meant by calling the series a hierarchy—that the sciences severally develop historically from the less scientific to the more scientific or "positive" form, in the order of their abstractness as indicated, those coming after being dependent upon those going before for the scientifically reliable truths with which to deal with their own less abstract, more complex problems.

This logical arrangement of the general sciences is indicated in the accompanying chart (No. 1). The chart is constructed to suggest, in brief and sketchy form:

1. The enumeration of the grand divisions of science in their logical sequence.

2. That this sequence is determined by the fact that each division interprets the universe in terms of a central conception, in the process defining the conception used. Thus logic may be defined as the science of unity, mathematics as the science of magnitude, physics as the science of energy, chemistry as the science of matter, biology as the science of life, psychology as the science of consciousness, and sociology as the science of society.

3. That in defining its own conception of the universe,

[1] An apparent exception to this rule is the case of physics and chemistry. Because of our modern tendency to define matter in terms of energy, i. e., in terms of mass and motion, sometimes stated as electrical activity, chemistry tends to become a branch of general physics.

I. CLASSIFICATION OF THE SCIENCES.

Grand Divisions	Logic	Mathematics	Physics	Chemistry	Biology	Psychology	Sociology
Main concepts being defined	Unity	Magnitude	Energy	Matter	Life	Consciousness	Society
Main concepts used as previously defined by science		Unity	Magnitude Unity	Energy Magnitude Unity	Matter Energy Magnitude Unity	Life Matter Energy Magnitude Unity	Consciousness Life Matter Energy Magnitude Unity
Space and time aspects in scientific method	Subject Predicate Copula	Problem Solving process	Statics Kinetics	Valence Reaction	Species Evolution	Elements Development	Organization Progress
Synoptic branches of the sciences	Philosophy Metaphysics Epistemology	Symbolical logic Theory of numbers, of Space, of Infinity, etc.	Mechanics Astronomy Geology Chemical dynamics, etc.	Theory of matter Gases Liquids Solids, etc.	Botany Zoology Ornithology Ichthyology Paleontology etc.	General psychology Social psychology Transcendental psychology, etc.	General sociology Geography Anthropology Archeology Social origins History, etc.
Specialized branches of the sciences	Formal logic Argumentation Logical critique of each of the sciences, etc.	Arithmetic Algebra Geometry Trigonometry Analytics Calculus Variable functions, etc.	Gravity Sound Heat Light Electro-magnetism, etc.	*Inorganics* Mineral acids Halogens Metals, etc. *Organics* Aliphatics Hydrocarbons Aldehides Alcohols Vegetable acids Esters, etc. Aromatics Benzine Carbohydrates Dyes, etc.	Bacteriology Anatomy Physiology Histology Neurology, etc.	*Projectives* (will, or motor reactions) *Reflectives* (Intellect, or cognitive reactions) *Affectives* (feeling, or evaluating reactions), etc.	Hygiene Economics Communication Pedagogy Ethics Politics Recreations Esthetics, etc.

NOTE: For other classifications see: Bacon (*Intellectual Globe*), Comte (*Positive Philosophy*), Spencer (*Classification of the Sciences*), Bain (*Logic*, pp. 627 ff) Pearson (*Grammar of Science*, pp. 504 ff), Thompson (*Introduction to Science*, pp. 81 ff), Flint (*History of the Classification of the Sciences*).

each science, with the exception of logic, employs as means the defined conceptions of the logically prior sciences. Logic, being the science of the very process of developing conceptions, must rely, for the testing of its own definitions, upon the immediate consciousness of unity as practical consistency in experience. This is the "logic" of experimentation. Of course, all sciences use experiment, but logic has to rely on it alone for the "given" means of verification.

4. That the elementary space and time aspects of experience appear in the method of all science as discriminations of structure and function, fact and change. Each science regards its subject-matter as a given system developing, and aims to define the development, i. e., to state the succession of forms the system assumes.

5. That the branches of each science develop from the synoptic to the specialized form, the former being the earlier effort to assemble data covering a wide range which is later more accurately classified and defined.

Let us now examine how each of the general sciences employs the historic method in defining the unity of experience from the point of view of its special conception.

Logic, we have said, studies the method of the formation and solution of all problems. It is just thinking become critical of its own method, so as to make the solving of the problem more swift and accurate. Let us emphasize again that logic is the science of unity, explaining what unity is and how it is maintained by thought as consistency, continuity, harmony in our experience. "That which, by the law of its being, intellect seeks above all and perpetually pursues and loves, is harmony. It is for a home and a dwelling with her that intellect creates a world; and its admonition is: Seek ye first the kingdom of harmony, and all these things shall be added unto you."[2]

[2] Keyser, *The Human Worth of Rigorous Thinking*, p. 23.

"*The problem of logic* has a more general and a more specific phase. In its generic form, it deals with this question: How does one type of functional situation and attitude in experience pass out of and into another; for example, the technological or utilitarian into the esthetic, the esthetic into the religious, the religious into the scientific, and this into the socio-ethical and so on? The more specific question is: How does the particular functional situation termed the reflective behave? How shall we describe it? What in detail are its diverse contemporaneous distinctions, or divisions of labor, its correspondent *statuses*? In what specific ways do these operate with reference to each other so as to effect the specific aim which is proposed by the needs of the affair?"[3] With logic in the wider sense, as a critical theory of the relation of the social functions to each other, we shall have to do later when we discuss the question of scientific method in sociology. But at this point, where we are dealing with the method of the reflective function as such, in its systematic form as science, we are concerned with logic in its more specific form as the critique of science. The business of logic in this narrower sense, then, is to define for us the function of thinking itself, and indicate the conditions under which it fulfils its function.

Thinking arises as an effort of our activity to pass out of conflict and failure of function into union and achievement of function. In this process, logic discriminates two methods: deduction and induction. Deduction takes the familiar form of the syllogism, A is B, B is C: therefore A is C,—reasoning from the nature of a known whole system to the nature of its particular parts. There is, therefore, in deduction no real progress or growth of thought into a larger or previously unknown unity, no real transformation of an existing conflicting system into a new unified system, but only a clearer definition of particular

[3] Dewey, *Essays in Experimental Logic*, pp. 97-98.

things in terms of their places or functions in a system already well known. In induction, however, we do make progress in the transformation of conflict into cooperation by getting beyond the old system altogether. In accomplishing this, induction takes the form of the inference, at first in the form of a question: Given A, is A C?—which being interpreted, means, Is this present, conflicting, unsatisfactory system, A, resolvable into the harmonious, satisfactory system which I guess is C? In both the deductive and inductive forms of judgment the copula, "is," signifies a mental action. In deduction the act of solving the problem has taken place in the past, and we are only reviewing it to make clear the steps taken or the factors of the solution previously reached. Deduction, therefore, serves as an instrument of analysis—it tells what particulars to look for and expect in a given situation: if we have the system A, we infer we have as factors that make it up the particulars B, M, X, Y, etc. Thus deduction, by itself, simply reaffirms, reasserts, the existing present system, without transforming it or getting us beyond it.[4] But if this present system is felt to be conflicting and unsatisfactory, then induction is already at work in it, trying to formulate the new, more satisfactory system into which the old one must develop. In thinking we oscillate between deduction and induction; both are necessary; either one used alone or overemphasized leads to confusion and disintegration of experience.

Thus, deduction is analysis, whose function is to bring to attention the factors of the old system. Of itself, deduction does not develop a new system, it merely emphasizes the old, it does not employ experiment—for the relations

[4] Cf. Baldwin: *Genetic Logic*, Vol. II, pp. 331-3332: "Inductive inference, therefore, is the process of the constitution of wholes of meaning in this or that control sphere; while deductive inference or implication is a movement of thought, whether one of relatively simple inspection or one of relatively detailed elucidation, within the whole already in some sense grounded or established."

of the system are all known; and for the same reason it does not develop new truth. Induction, on the other hand, is synthesis, whose function is to construct a new system, in part of factors of the old, and in part of new factors developed in experiment. Induction alone, however, can no more develop a new system than can deduction. The analysis of deduction is required to bring out both the factors of the old system that must be thrown out as no longer serviceable, no longer true, and also those that are still serviceable and true. Thus, the more deduction insists on the old system, the more induction insists on the new. (Where we have the dangerous extreme idea of the civil law as insisting on subservience of the individual to the present system without any change in it, there we are sure to have the opposite dangerously extreme idea of the entire abandonment of the existing law and system, in favor of an impossible, entirely new system.)

Logical Nature of a Law.—What thinking is always trying to do, as a means of keeping up the unity and growth of experience, is to define the relation of something concerning the thinker to the whole in which it is a member. General philosophy calls this action of thought "defining the relation of the particular to the universal." Whether it be the relation of the organ to the organism, of the word to the sentence, of the factor to the solution of the problem, of the habit to the character, or of the individual to society—in every case it is the definition of the relation of a member to the body whose unity and identity it cooperates with the other members to maintain and express. This is what science means by a law. Whether it be a so-called natural law of physical nature formulated in a laboratory, or a civil law of society (which, in a sense, is just as natural) formulated in a legislature, the law is in principle the same: a statement of the observed and tested relationship of a member to a body of members in which it

has its meaning and its existence. The law thus universally is a statement of a set of given conditions and a logical (ultimately practical) consequence, in the form, If A, then B. Assuming A represents the general system or body as given, and B the member, then the deductive form of the law would be as above: if A, then B, indicating that in a given system or body, A, a particular member, B, is operating at a particular point in a particular way. The inductive forms of the law would be the reverse: if B, then A, indicating that, given a member, B, as behaving in a particular way, the system, A, of which it is a member is inferred from its behavior. So astronomers, from observation of the sun and planets have inferred the nature of the solar system; and zoologists, reasoning from a few bones of an extinct or a new species of animal, have constructed with considerable accuracy the whole skeleton. Science thus enables us to predict, to anticipate, to construct as an ideal a system of relations in which we ourselves must function as factors in the future, and by this anticipation science enables us to reconstruct our own habits so as to function efficiently in the new system.

Transcendental Action of Judgment. — How do our minds achieve this anticipation? How do they transcend past experience in the construction of the new system? How do they proceed to set up this new system in ideal, so that, as a working hypothesis, it shall express the probable new relationship of the member to the system, and, upon test, turn out to be the new truth that guides our action in meeting some later situation? Every act of thought, every judgment however vague or abbreviated, every sentence, has, as before stated, a subject and a predicate. In the live judgment, where thought is actively engaged in trying to identify something, to place it in a system of relations, the subject is the accepted, unquestioned aspect of the situation or thing presented; the predicate is the un-

certain, questioned aspect, something tentatively affirmed but not immediately apparent. That is, the subject is the fact aspect and the predicate is the hypothesis aspect. In the beginning of the act of thinking, as, for example, in trying to identify an object approaching in the distance, the judgment takes the form: This is what? But even in the beginning, the subject is not merely "this" and the predicate is not merely "what," for the subject will have some immediately identified and accepted characteristics, such as color, size, and movement, and the predicate will consist of an immediately suggested hypothesis or series of hypotheses, such as man, horse, etc., because of the fact that every stimulus—every excitant attended to—means that a response is going on, that habitual, reflex actions are taking place through race instinct and other unreflective reactions derived from the past, representing organic functions maintaining their adjustment with the environment. There is, in other words, a functional adjustment already at work when reflection begins, and reflection arises because the adjustment has become insufficient to enable our functions to maintain the unity of our experience. As long as we are unable to identify the object, we feel impulses to move in contradictory ways, corresponding to the various hypotheses we entertain about it. Is it a friend expected?—is it a mad dog?—is it a creature we have never seen before, but like a horse? Each of these hypotheses brings to mind certain characteristics of color, size, movement, etc., which we compare with the like characteristics of the object in question. The predicate as hypothesis, therefore, is a system of relationships developed as a solution of past problems of adjustment and temporarily accepted as a truth unquestioned for the purpose of identifying the subject and securing adjustment in the present problem. If, by the experimental tests of observation, motions, calls, etc., we find that the features and behavior of the

object are largely identical with those of our hypothesis, then we are able readily to identify it, classify it, take a definite, unified attitude toward it. If, on the other hand, we have no classification, no truth, no system, within which the object will cooperate as a member, then we have to develop a new class, a new truth to explain it. We observe it and stimulate it more carefully to get a larger number of its reactions and characteristics, at the same time comparing them with those of the class or system in our experience most nearly like the object, until our own reactions to it, beginning as if it were in the familiar class, become definite and assured as new habits in a new system. Thus, some of the factors of the old system are carried over into the new, to serve as the bridge of truth between the two. If it were not for these old factors, which represent old habits in ourselves found to be still useful in the new situation, we could not deal with the new object at all, in fact we should be unconscious of it. But by our direct experimental dealing with the new object we have set up new habits which define the new factors of the new system.

This problem of the development of the subject-predicate distinction is perhaps the most profound and far-reaching question in philosophy; for it involves the whole question of the reality of the growth of the universe, and, in human consciousness, the question of how a new idea or thing can possibly originate. The critical cases in point are the earliest experiences of infancy, and the inventive activity of the genius—the scientific discoverer or artist. My own view is that consciousness, as human beings experience it in its reflective form, is not, in its elements, essentially different from the universal evolutionary process of adjustment by stimulus and response, but is just an advanced stage in that process. The critical case of rudimentary reflection in earliest infancy suggests that distinctions of subject and predicate must, in some sense,

antedate birth as factors of adaptation and of growth. If we are to hold consistently the doctrine of an evolving universe we must believe that consciousness is not an alien entity breaking into evolution from outside at some point—say, where self-maintenance or where self-consciousness is assumed to begin; but is rather, in its essential elements, the universal process of adaptation itself, existing not only in the sub-human and sub-animal worlds, but also in the so-called inanimate world, as the function of stimulus-response in all activity, now being recognized in the electrical theory of matter. In this stimulus-response process, all the way down the line the consciousness of the higher, later forms seems, as a matter of observed fact, to help in giving direction to the process in the lower, earlier forms—conspicuously, for example, in the case of parent and child—but not without the initiative and cooperative effort of the latter. In the case both of the child and of the inventor making a new discovery—wherever intelligence is promoting growth—it may well be that suggestions from higher intelligences are cooperating with the initiatives of the lower to produce the adaptations necessary for growth in both. This view seems to do justice to the claims of both the intuitionalists and the rationalists, and offers a logical basis for a democratic theology, a democratic politics, and a democratic educational policy.

Practical Nature of the Criterion of Truth.—We have been maintaining that logic is the science which explains the meaning of thinking, in terms of the concept of unity or consistency. As already suggested, this conception means primarily the system of our own personal activities cooperating to maintain a satisfactory continuity of our experience. In the last analysis, it is the progressive realization of this conception in practice which serves us as the criterion of truth. As every problem means an effort to change a confusing, uncomfortable diversity into an in-

telligible and, somehow, comforting unity, any statement of conditions that guides us in making the transition, and thereby is identified as a consistently cooperating factor in the solution, we call truth; any statement which does not give us the solution, does not lead to satisfactory unity, or is inconsistent with it, we regard as error or falsehood. The phases of inference, deduction, induction, agreement, disagreement, etc., which logic discriminates in our thinking, are all subordinate functions in our effort to formulate the conditions of the situation, so we can make them maintain the growing continuity of our experience in the emergency when the rapid development of new, incompletely incorporated factors threatens to disorder and disrupt it. The necessity of maintaining the union requires that we formulate the law by which we can make the new factor cooperate to that end as true; or else, finding it cannot thus cooperate, that we cast it out as false. The standard of truth, as for all other values whatever, is the maintenance of the union. In other words, experience *as a whole* is the standard by which we test the truth or worth of any phase of experience.[5]

[5] The process has been illustrated by the case of a man lost in the woods. who, trying to find his way home, has to devise a theorem, plan, or hypothetical map of his situation, in which the known features in his immediate vicinity—the slope of the land, the direction of the streams, the direction of the sun, etc.—are used as suggestions of the unknown parts connected with them beyond his observation. He proceeds to solve his problem by going from the known to the unknown in accordance with his hypothesis, and reaches a solution when he proves his hypothesis true by arriving home. This illustration, given originally by Professor Dewey (see his *Essays in Experimental Logic,* p. 237ff), has been criticized by Professor Baldwin, who dissents (incorrectly, I think) from this view of the criterion of truth, which he calls the "action theory." (See his *Genetic Logic,* Vol. II, p. 345ff.) The controversy turns on the old question of the nature of success. Professor Baldwin asks, "What has constituted the correctness, or truth, of his plan?. . . .How does the man know his action is successful? The only answer is. . . .by ***the perceptual experiences*** found to be what the thought or memory presented in image. . . . The test, then, is a ***perceptual experience fulfilling the details of the plan that guided his action***. . . .The 'success' necessary, therefore, does not attach to acting thus or so." Professor Dewey answers (*Essays,* p. 240), "If we exclude acting upon the idea, no conceivable amount or kind of intellectualistic procedure can confirm or refute an idea, or throw any light upon its validity. . . . .If by acting in accordance with the experimental definition of facts, viz., as obstacles and conditions, and the experimental definition of the end or intent, viz., as plan and method of action, a harmonized situation effectually

Significance of This View of Truth and Its Criterion.—Now this doctrine—that the standard is the union, and that truth is instrumental, that truth is an invention which helps to maintain the union, and, when ceasing thus to function, must be repaired or discarded in favor of a more effective form,—this doctrine has some interesting logical implications.

In the first place, union or experience as a whole must mean more than what we ordinarily mean by individual experience. As the individual is a social member, experience *as a whole* must mean social experience so organized that, as it focuses in the individual, the individual's activities are satisfactorily unified and his services to the union increased in value. Likewise, the union must mean the universe so organized that the individuals carrying on its functions find their activities satisfactorily unified and effective for supplying their needs. (This can be made clearer when we come to discuss the relations of the social functions to each other.)

In the second place, this doctrine of the instrumental nature of truth and the normative nature of the common life, completely reverses the fundamental relations of these conceptions as they were held from the time of the ancient Greeks to our own day. Formerly, the universe being regarded, not as growing, but as fixed, truth was also regarded as a fixed thought-copy of the universe of which portions were progressively made known to the individual,

presents itself, we have the adequate and the only conceivable verification of the intellectual factors. If the action indicated be carried out and the disordered or disturbed situation persists, then we have not merely confuted the tentative positions of intelligence, but we have in the very process of acting introduced new data and eliminated some of the old ones, and thus afforded an opportunity for the resurvey of the facts and the revision of the plan of action." In other words, the test and criterion of truth is the practical unity of our experience as a whole resulting from our acting on an idea or plan assumed to be true. Being lost means disunion and confusion culminating perhaps in hunger and death. Home means not merely a "perceptual experience," but union, consistency in active experience—which is the test of success. Any other idea of the matter has across it the shadow of the old conception of thought as a mere copy of an ontologically external reality.

not mainly or in principle through the effort of human intelligence (which was considered as alien to the truth), but through revelation by "authorities" acting by "divine inspiration." This was the dominant theory of truth quite naturally during the centuries when, the means of knowledge being limited and monopolized by the few, the masses of the people were like children under the tutelage of their autocratic rulers. The masses have largely outgrown despotic tutelage. The democratic revolution has brought, as its very heart, a thought-revolution as sweeping as that of the Copernican theory of thé solar system. It is therefore no accident, in this day when the citizen is becoming the sovereign, that truth as an autocrat is being replaced by truth as a servant. Man is not made for the law, but the law is made for man. If, then, man—mankind—organized, united, growing society in which the individual attains real freedom,—is indeed the end and standard of all validity and worth, we are under the imperative necessity of defining that standard more accurately than we have yet done.

In the third place, truth, as our most important means of keeping up the continuity and growth of experience, is, as has been suggested, a bridge between the past and the future. Like all other bridges, it should be built as strong and permanent as possible, and should be kept in good repair with a minimum disturbance to the traffic. Every emergency of experience requiring the action of judgment to maintain its continuity, is like a chasm over which we find we must pass, and truth is the tested, reliable bridge, binding the two sides together into one continuous experience. Every passage over the bridge of truth to some extent reconstructs it, enlarges its meaning and usefulness —but specialists, called scientists and philosophers, are required to assist in reconstructing it fast enough to sustain the increasing commerce of the world. Any inexpert or careless tampering with the bridge is, of course, resented

by humanity as dangerous to the common welfare. The bridge derives its form, quality, and permanence from the nature of the traffic it serves, not *vice versa*. No doubt, this way of putting the matter is sufficiently irritating to the feeling of those who hold to the older theory of truth as an external copy of a fixed reality, but the logic of modern science and practical thinking seems to be dead against their view. The fact seems to be that science and other forms of experience are continually improving the bridge of truth so that subsequent heavier trains of experience can operate to supply the growing needs of the world.

MATHEMATICS, like every other science, has its origin and application in the concrete problems of our social life, whether they be those of navigation and surveying, of buying groceries at the store, or of simply trying to reach an object with the hand. From these concrete problems mathematics abstracts, that is, gives attention to only the quantitative relationships (as 2, triangle, etc.), assuming or ignoring all the other aspects.[6] Thus simplified, the subject-matter is easier to think about in a clear and definite way. The science begins, both historically and logically, in the axioms, that are logical definitions of the mere quantitative aspects of our own sensations and motor activities, out of which all our notions of magnitude arise. It is especially by reflection on our own movements,—their repetition, change of direction, and duration, embraced within the continuity of our consciousness—that we construct our time and space axioms of mathematics, such as "$2 \times 2 = 4$" and "The shortest distance between two points is a straight

[6] Professor Keyser, in his interesting lecture on mathematics, takes issue with this position (*op. cit.*, pp. 276-279). He points out the wonderful expansion of mathematics in recent years, and shows how logic and mathematics have met in the borderland of symbolic logic, as developed by Leibniz and others—and is inclined to identify mathematics with all strictly valid thinking. I believe it is more useful to regard logic as the prolegomenon of mathematics, and define mathematics as the science of the unity of magnitudes.

line." We may say that the simplest axioms constitute our consciousness in its lowest terms, as vaguely defined in the early experience of the infant, or in the beginning of our attention to particular objects in any problem. They are the premises in concrete thinking just because they are the simplest statements of the relationships between our initial conscious impulses, prior to which we are not able to distinguish any antecedent conscious conditions. By means of these initial definitions mathematics solves its simplest problems of quantitative relations; and then using these solutions as truths for the solution of more complex problems, and these again for others, it progressively constructs a series of judgments, each depending for its validity upon a prior, and forming a branching "tree" of subjects, from simple arithmetic to the higher theories of variable functions. These subjects constitute an elaborate series of thought-tools, adapted to guiding judgment in a series of practical problems of increasing complexity, from measuring a piece of goods to the construction of a railroad bridge, or the location of a star.

How, then, does mathematics, as a typical science, solve a problem? Take, for example, geometry, and the simple problem of determining whether the theorem be true that the sum of any two sides of a triangle, ABC, is greater than the third side. Of course, this is no longer a real problem to us of mature years because we have so often proved it true by acting in accordance with it in moving or going from one place to another. But there was a time in infancy when for each of us it was a real problem; and the question is how our minds proceed to determine the truth. In the first place, we deductively discriminate familiar aspects of the strange situation, ABC, confronting us. If the situation were entirely familiar or had no familiar aspects we should not in either case, be conscious of it as a problem at all. The problem consists in determining the

relationships of the unfamiliar to the familiar so as to comprehend the situation as a whole. The familiar means an old way of thinking and acting, the unfamiliar means a modification of the old into a new way demanded by the new situation. Let us assume that the old habit of action has been direct, i. e., movement aiming to reach things by a straight course; therefore in practice we have been accustomed to the axiom—without definite formulation but operating in the form of habit as a truth—that a straight line is the shortest distance between two points. The straight lines would be the familiar aspects, then, of the new triangular figure, and any of them constituting a side, as AC, would be shorter than any other line, as ABC, passing through the same points. Applying the same reasoning to each side in turn, the theorem or hypothesis is established as a truth that can be similarly used to develop still other truths and guide activity. In this process both the old familiar figure, the line, and the new unfamiliar figure, the triangle, have acquired new meaning. The line, by becoming a member in a new system, functions as a new thing in our experience; and the triangle, as being composed of lines in a definite relationship to each other, becomes defined and available for use in reaching other conclusions. Practically, we may say we have thus learned that we can reach a point not only directly but also, with more time and effort, by a roundabout way, if we have the two ways definitely related to each other in the same system or map of conduct.

Now mathematics constructs systems of relations between mere quantities or abstract magnitudes, and tests them out as truths, in the same general way that the biologist does his systems of bones. The typical form in which the mathematical systems are stated is the equation. A mathematical equation is just a symbolic or shorthand description of a series of operations ending in an an-

swer—a confirmed hypothesis which states a satisfactorily unified experience. If we say $6 \times 5 = 30$ we mean (since multiplication is a quick way of performing the operation of addition), take six like systems, each containing five like things, and assemble them all together into one system—and you will have thirty like things in the new system. To the person who performs this operation for the first time, thirty is a genuinely new system of experience, reached by taking six of the old familiar systems of five units, and assembling them so that they lose their old identity, their old separate unity, and merge into the new unity of the system of 30. Thus, an equation as a statement of a method of solving a problem, is not merely an expression of static, quantitative identity of the terms of the two sides, but rather an expression of dynamic, qualitative change of an old experience into a new one, in time and space. The operative symbols, $\times$ (times) and $=$ (equals), indicate the dynamic character of the equation, the changes in the process; the quantitative identity of the two sides indicates the continuity in the process—one continuous transformation of the old into the new. The asserted equality of value of the two sides means that the process of transforming the old system of experience into the new is equivalent to the new.[7]

The work of mathematics is to make accurate and reliable our calculations of merely quantitative relationships, but obviously it cannot be our sole guide in the business of life. The very fact of work means energy, about which

[7] Stated in terms of moral experience, this means that the conduct which achieves the end has all the value of the end; or, in other words, the end or ideal is the guiding, evaluating factor in conduct—not something lying *beyond* it, and therefore unattainable. The end is the function. In a democratic, united, normal society, "Virtue is its own reward," art is its own reward, fellowship is its own reward, industry is its own reward. If the process leads to a valuable result, it has the value of the result—to whoever realizes the value. The value of an end, an hypothesis, an ideal, is the degree in which the process of realizing it introduces order, freedom, and satisfaction into experience. The social problem is just that of enabling all the workers to experience the full value of their work—in other words, to achieve a democracy, a union in which they shall all be members.

mathematics, as such, tells us nothing but the quantities of it; but we need to know also how it may be developed, changed from a kind useful for one purpose into a kind useful for another purpose. For an explanation of this we have to look to the science of physics.

PHYSICS, then, takes another step in developing an answer to our social problem by making clear to us the nature of energy as the power of doing work. It analyzes the different kinds of energy that we distinguish by our different senses, as mechanical energy, sound, heat, light, electricity and magnetism, gravitation, expansion of gases, and in doing so treats of matter only as a manifestation of energy, that is, as mass in motion. As an attempt to explain from the standpoint of energy how a universe is developed, physics is also historical in its method. It is a deliberate effort to formulate the method by which energy is transformed from its "natural" into its artificial manifestations, to give us the means of catching energy at its birth, and training it to the work of ordering the universe to serve the interests of man. In doing this physics has its genetic classifications of things as gases, liquids, and solids—as atoms, molecules, and masses—each with its specific motion as a function of its energy. Thus, in telling us what iron is, physics tells us the amount of heat required to change it from a solid into a liquid and a liquid into a gas, tells us what its specific gravity is, how well it conducts electricity—in short, how it behaves in furnishing energy for the world's work.

But magnitude and energy are obviously not the only general aspects of the universe that we have to take into account in dealing with it satisfactorily. Our senses of taste and smell especially indicate that things are made of quite radically different materials, and it is the science of chemistry which undertakes to carry us a step farther

in controlling our commerce with the universe, by showing how we may produce things by controlling the materials of which they are made.

CHEMISTRY, as a science of matter, undertakes to tell us the story of the composition of things out of their physical elements, and points out how we can get control of the elements of some things that we want to use, by decomposing other things that we do not want to use (except as decomposed). When, for example, chemistry tells what water is, it tells how water has been historically developed, how we may produce it by extracting hydrogen and oxygen from things constituted partly of them, and then recombining them intimately in the proportions of two volumes of hydrogen to one of oxygen. The formula of water, H_2O, is thus a shorthand symbol of a material process of genesis (we may even say, of Genesis) in which the relations of chemical combination of certain elements are indicated. In its definition of things as elements of matter undergoing decomposition and recomposition, chemistry employs the general conceptions of magnitude and energy developed by mathematics and physics, and, of course, their classifications, but adds classifications of its own, in the historical form as elements, simple (inorganic) compounds, and complex (organic) compounds. This, science tells us, is the historic order: elements, non-living compounds, living compounds; and chemistry aspires to point out the methods of chemical reconstruction throughout the entire series.

But, after all, when we want to build a bridge of iron, drink water, or make seeds germinate, we have to know more about the universe than mathematics, physics, and chemistry assume to tell us. We have to know more about the behavior of things, for some things have a remarkable power of initiating and controlling changes, physical and

chemical, that are not accounted for by the formulas of these sciences.

BIOLOGY, as the science of life, approaches another step toward a solution of our social problem by defining exactly the conditions under which certain things we call living. initiate and control changes so as to perpetuate their own identity—that is, cause changes to take place as a periodically recurring cycle that maintains and develops the body through which they take place, against the forces that would otherwise disintegrate it. So biology adds a new general conception or class of relationships to those of the logically prior sciences by directing attention especially to the life process, and defining things, iron, water, seeds, etc., as factors in this process. And just as logic, mathematics, physics, and chemistry, each from the point of view of its special conception, classifies an historical continuity of living relationships, by classifying living forms in an evolutionary series from the lowest—i. e., earliest—plants to the highest—i. e., latest—animals. Biology thus endeavors to show how an individual maintains itself, how it produces other individuals, and how types of living individuals develop into succeding types.

Take an illustration of thinking involved in biology, say, that of a naturalist, whose business is to define the terms and conditions of our reactions to our physical environment, so we may maintain the unity of our experience under new physical circumstances. Suppose he is walking in a field and sees a bird fly and alight at a short distance. Since he is looking for field birds, having in mind the familiar system of their characteristics, he quickly notices the markings as those of a pheasant. If nothing in the situation seems to contradict the conclusion, his judgment may end there as a rapid alternation of induction and deduction, chiefly the latter. As he is looking for something new,

his mind is at the start in the inductive attitude, but the first perceptions having so vividly suggested the pheasant that that conception dominates his thinking, he deductively enumerates the characteristics of the bird before him and passes on to some other judgment. But suppose something in the situation does seem to contradict his first conclusion. Suppose he notices the bird has, in addition to some of the familiar characteristics of the pheasant, also other markings and manners not of that class as he has known it. The appropriate reaction toward the creature is thus in doubt—what the present system of experience is, is uncertain—and this uncertainty is reflected in the transformation of the original tentative conclusion into a working hypothesis to be experimentally tested. Our scientist whistles to the bird and hears in answer a strange call. He approaches it and observes more closely its appearance. This may suggest some other hypothesis, e. g., that the bird belongs to some other class than that of pheasant, perhaps more exactly a grouse or large quail. Repeated comparison of the characteristics of the bird with those of known species may convince the naturalist that he has discovered a new species of pheasant—determining conditions of new forms of human activity. If the species proves to be specially good for food, it may be rapidly killed off, or may be protected and multiplied with consequent rapid alteration of the insect and plant life of its environment, i. e., with considerable transformation of the world in directions determined by the interests of man.

This is what any discovery means: a dynamic transformation, not merely a static revelation. And let it be noted the transformation takes place, not only in the conditions of objective experience, that is, in those habitual experiences where reflection is not prominently concerned, such as dining, reaping, admiring colors, etc., but the transformation occurs also in the conditions of subjective ex-

perience as a change in the very truth by which the transition from the old to the new was accomplished. There is no sense in which any *particular form* of truth exists prior to the discovery—the thinking process through which it is constituted as outcome of the effort to maintain the unity of experience in the emergency of a conflicting situation. If it was formerly true by tested and accepted definition that all pheasants had brilliant plumage, then it was not true that some pheasants have drab plumage until after some exigency of maintaining a unity of experience resulted in the modification of the genus "pheasant" to include the species with drab plumage. In this way every fact added to existing knowledge transforms preexisting fact and makes truth different from what it was before. In a growing universe there is no absolute ultimate fact. But biology does not ask especially what part consciousness plays in the life process. This explanation is left for psychology to define.

PSYCHOLOGY defines consciousness as an especially expeditious method of control in the life process. It is awareness of relationships and values, in a transition of activities from confusion to cooperation, from disunion to union, the awareness itself operating to facilitate the transition, harmonize the relationships, and increase the values of the activities.[8] Of course, psychology is as unable to give a complete definition of consciousness as logic, mathematics, physics, chemistry, and biology are to define completely—that is, practically—their own special conceptions: for each conception can be *practically* apprehended only in the light of all the others, including that of society. Each science uses, as clear and definite for *its own purpose,* the conceptions of the logically prior sciences, but in doing so, as we

[8] The modern definition of consciousness excludes the idea that it is an entity composed of a "soul substance." The psychical or subjective is the system of evaluating functions that maintains and develops, at the same time and in the same degree, our personal identity and the unity of society.

have seen, it modifies, enriches, the meaning of the conceptions used; and it assumes as a vague background of its thinking the conceptions of the logically subsequent sciences. Thus psychology may undertake to define consciousness in merely physical terms, as a change of environmental, overt forms of activity (matter in motion) into organic—neural—activity, such that the transformation issues again in environmental activities. But if we stop here we have totally failed to define consciousness. For the essence of consciousness consists in the values and change of values of activities, with reference to the maintenance of our own personal unity. The concept of the physical thus gets a new meaning by the necessary introduction of the concept of value, inherent in consciousness. And the concept of value, or of consciousness (as used by psychology) vaguely anticipates the concept of society (as developed by sociology). Value is developed in the performance of a social function. The individual is a social member. We cannot understand therefore what consciousness means (that is, as something leading to practical ends) until we understand more definitely about society as sociology interprets it; for all practice is social, i. e., involves social relationships intrinsically. It is indirectly for the valuation and control of these intrinsic, practical, social relationships—for the satisfaction of human interests, the discharge of human functions—that the concepts of all science are developed.

In interpreting the phenomena of consciousness, psychology, true to the method of science, classifies its subject-matter in a genetic series as successive phases of consciousness—successive forms of judgment of increasing comprehension, adapted to situations of increasing social complexity—from vague and fleeting sensation through perception and reasoning to the higher forms of the moral and esthetic judgment. By these classes of judgment,

psychology undertakes to define in terms of conscious processes the various mental attitudes, habits, and ways of acting that people are observed to assume. But, as we have seen, these judgments presuppose certain social situations, to which they are relevant as the agencies through which social conditions are evaluated and adjusted in the development of the larger life.

Sociology, then, undertakes to construct the classifications of the social situations which call forth the characteristic reactions of the individual, as defined in psychology. In other words, sociology endeavors to explain society as a system of cooperative relationships between persons so that the individuals cooperating can adjust their conduct to the satisfaction of their needs. In this work, social psychology has recently been developed as a connecting link between the older psychology and sociology, to show the relationship of the individual, as psychologically described, to the world of people, as described by sociology. Mob psychology, pathological psychology (that of insanity, etc.), and transcendental psychology (that of mediumship, etc.) also have been recently developed to interpret social phenomena that psychology seems best able to explain. But in interpreting these and all other social phenomena, sociology is obliged to employ all of the major concepts defined by the logically prior sciences: consciousness, life, matter, energy, magnitude, and unity; and in so doing, deepens their meaning.

Chart II, Classification of the Social Sciences, is inserted here to suggest, in addition to the points of Chart I, how the particular social sciences are rapidly developing as reflective specialization upon the various problems of social practice. If, as we are maintaining, any science is merely a clarified development of common-sense thinking, then the logic of any science is an exposition of how

its method does interpret and clarify ordinary thinking. Suppose we take, as a single illustration, the logic of law-making as the basis of the growing science of legislation. While doubtless legislators, as a rule, have not been conspicuous for the use of scientific method, yet as above suggested, the operation of intelligence in the making of civil laws proceeds by the same universal process of thinking as does the formulation of a law of physical nature. And

II. CLASSIFICATION OF THE SOCIAL SCIENCES.

Synoptic Sciences

General sociology	Geography	Social origins
Anthropology	Ethnology	Social evolution
History	Archeology	Municipal sociology
		Rural sociology, etc.

Specialized Sciences

Sciences of Maintenance		*Sciences of Reflection*	
Hygiene:	2 *Economics:*	3 *Information:*	4 *Pedagogy:*
Eugenics	Commercial geography	Language	Primary
Dietetics	Extraction	Investigation	Secondary
Therapeutics	Technology	Statistics	Higher
Sanitation	Management	Accounting	Technical
Labor	Finance	Journalism	Homemaking
Family	Transportation	Bibliography	Medicine
Consumption			Business
			Communication
			Education
			Ministry
			Government
			Recreation
			Art

Sciences of Control		*Sciences of Recreation*	
Ethics:	6 *Politics:*	7 *Fellowship:*	8 *Esthetics:*
Conduct	Legislation	Etiquette	Dramatics
Theology	Law	Entertaining	Music
Homiletics	War and defense	Sports	Literature
Missions	Penology	Play	Painting
Philanthropy	Administration	Dancing	Sculpture
			Architecture
			Landscape art
			Craftsmanship

legislators are surely as much in need of science as are physicians and engineers. If we can make clear, then, what the universal process is in thinking as applied to lawmaking, we may be able to make legislation as scientific as biology or physics. We have seen that any truth is a statement of the relation of a particular to a universal, of a member to a system, determined as a solution of a past problem, and used without question as a means of reaching

a new solution—the method of organizing a new system. Any body of civil laws is a set of statements of the relations of individuals to society, determined as the solutions of past problems securing the effective cooperation of individuals in maintaining the social union. As society grows, as population increases and becomes more interdependent, we find that the union is continually tending to break down at certain points, for new methods of cooperation are necessary to maintain it; hence, new laws, as statements of the new methods, are continually necessary to enable people to understand how to cooperate.

The scientific legislator proceeds like any other scientist. He observes a breakdown of the union at a particular point, formulates an hypothesis of the kind of system which at that point would maintain the union, tests his hypothesis by public discussion and perhaps overt trial of unenacted custom; then states the social reaction against violation in the form of specific penalties, the reaction in favor of maintenance, as conducive to union, in the form of positive provisions for carrying it out. As old habits often appear under new conditions in disguised forms, we are not always able to perceive their consequences readily and judge them accurately, as in cases where we continue to punish a man for stealing a horse and praise a man for stealing a railroad. This is due mainly to the fact that the social union is always outgrowing our consciousness of its extent and cooperative requirements, as amply indicated in some quarters by insistence on mere nationalism as against internationalism. Internationalism is simply the inevitable, coming larger union, whose new laws of relationship we are endeavoring to state in the constitution of a league of nations.

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